Embryology of the Peritoneal Cavity

Introduction

This subject material is catastrophically difficult for most learners. We at OME think a large part of the problem comes from the longstanding use of imprecise nomenclature: call it pragmatic inertia, or the idea that it's easier to keep using misnomers (although when the names were given, they reflected the understanding of that era) than to try to introduce new naming conventions. We think that once you realize that the abdominal cavity is a literal cavity but not a Body Cavity (caps intentional), that a Body Cavity is not a literal cavity, and that there is no such thing as an intraperitoneal organ, the anatomy and embryology of the peritoneal cavity will be much easier to grasp. So, too, will be speaking of the topic histologically rather than from the perspective of the general surgeon looking at these structures in a patient opened up on the operating table (the key component of which—the mesothelium—is not even visible to the naked eye). After clearing up some of the nomenclature and reviewing the anatomy, we conclude by applying this learning to an account of the embryonic development of the peritoneal cavity and organs of the abdominal cavity (*sic*!).

All organs in the belly are inside the abdominal cavity but outside the peritoneal cavity. The **abdominal cavity** is not a Body Cavity and should be called the **abdominal compartment**. But it got the name cavity. That is because it is a literal cavity that is filled with organs—if you take organs out of the abdomen, there is space left behind. The abdominal cavity (compartment) holds all the organs in the belly, including the organ, the peritoneal cavity, which is not a space but a Body Cavity.

The Peritoneal Cavity Is a Body Cavity, Not a Cavity

Body Cavities are independent organs that consist of a mesothelium-lined sac of fluid. We didn't call these fluid-filled-sacs-lined-with-epithelium cavities. Medical science did. They are not potential spaces. They already have fluid in them. Body Cavities are fluid-filled-sacs-lined-with-mesothelium. Mesothelium is a simple squamous epithelium that lines Body Cavities. Body Cavities are named based on the organ they are next to. Unfortunately, the peritoneal cavity is the exception to the Body Cavity naming conventions. As we will see, many organs of the abdominal cavity (compartment) encroach on the peritoneal cavity (Body Cavity). In doing so, the peritoneal cavity's mesothelium gets **stretched** out and wraps **around** the encroaching organs. The etymology of peritoneum is derived from the Greek *peritonos*: *peri-* (around) and *-tonos* (stretched).

Ironically, the abdominal cavity (compartment) is an actual cavity. If you open the belly and remove the bowel, what's left behind is a gaping space. The abdominal cavity contains the peritoneal cavity (a Body Cavity), all the GI organs, and all the blood vessels, lymphatics, and nerves, as well as the organs that do not abut the peritoneal cavity.

The peritoneal cavity is a Body Cavity, an organ located in the abdominal cavity. A Body Cavity is a mesothelium-lined sac of fluid. The mesothelium is simple squamous epithelium. Therefore, being so flimsy, it is impossible to hold a Body Cavity in one's hands. Thus, to perceive a Body Cavity at all, one must use a microscope, and Body Cavities are commonly seen on histology as the simple squamous epithelium adjacent to a visceral organ. Thus it appears that the simple squamous epithelium belongs to the organ, the organ's outermost layer. The serosa of the GI tract does not belong to the GI tract, as the serosa is the mesothelium that belongs to the peritoneal cavity.

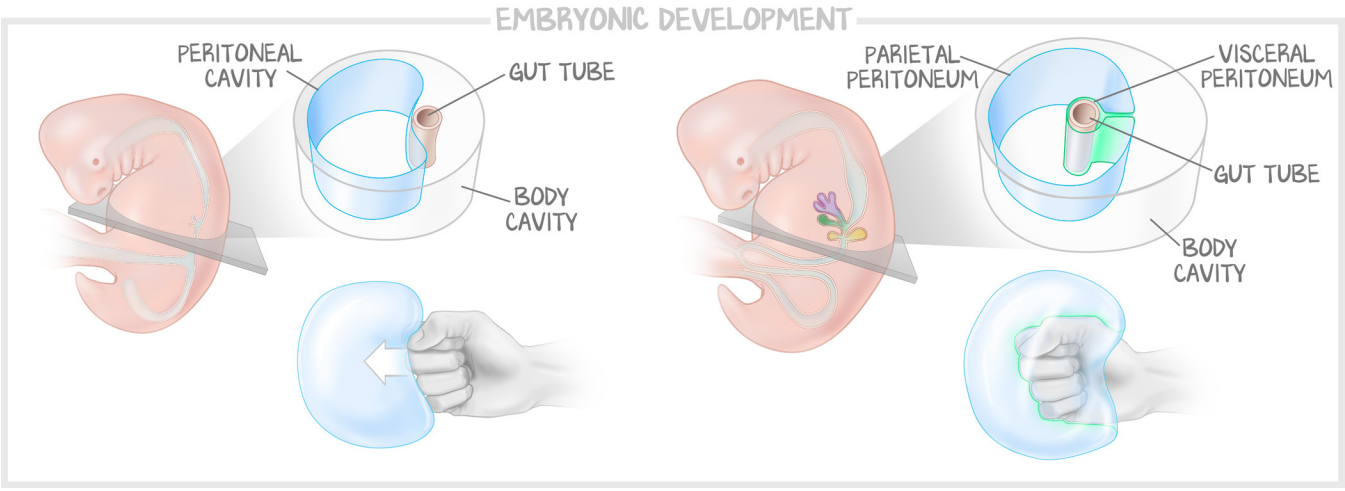

Figure 3.1: The Peritoneal Cavity Is a Body Cavity
The peritoneal cavity is a mesothelium-lined sac of fluid. A bag of saline is effectively the same thing, except its lining cannot replicate to accommodate more and more organs. Comprehension of how this process starts enables you to accept, but probably not deduce, how the rest of the process occurs. As the gut tube grows, it encroaches on the mesothelium of the peritoneal cavity. Much like the bag of saline gives way to the fist, the peritoneal cavity gives way to the growing gut tube.

It's easiest to think of mesothelium as a thin, but really long, cloth sheet. Take a look at your living room. Imagine if you draped a sheet over everything in the room. You'd see the shape of the furniture underneath it. In between furniture, the sheet would hang close to the floor. The floor. Are the pieces of furniture covered by a sheet in contact with the floor? Yep. All still connected to the floor. How about that nice subwoofer plugged into the wall? Is that on the floor? Yep. The floor is the posterior wall of the abdominal cavity (not the peritoneal cavity). That subwoofer is plugged into the wall to draw power, and it is connected to the rest of the sound system. You are now standing, looking down at the furniture covered in a sheet. You, looking down at the sheet, are the surgeon. The sheet is mesothelium. You can see the imprinting of the furniture under the sheet. That's visceral peritoneum. Between the pieces of furniture, the sheet hangs close to the floor. That's parietal peritoneum.

This next part takes some imagination, but hopefully, it works. Imagine continuing the sheet from the last piece of furniture up the wall, over the ceiling, and down the other side (using tacks and staples where needed so that it stays). All of that sheet? Parietal peritoneum. The walls, ceiling, and floor are the boundaries of the abdominal cavity. Between the sheet on the ceiling (parietal) and the sheet on the couch (visceral) is the peritoneal cavity.

That subwoofer needs power and connection to the sound system. Cords run from each. Where do they run? Along the floor under the sheet, from the wall and the floor. Those cords and cables are just like arteries, veins, nerves, and lymphatics. These come from the back of the abdominal cavity. They come from the floor. They may travel from the couch to the coffee table, or from the coffee table to the ottoman, but where are they? UNDER the sheet.

The peritoneal cavity is more difficult to understand than that. This is because this sheet-over-the-furniture is already getting pretty ridiculous with the sheet stapled to the ceiling. And it is about to get a lot worse. But do the thought exercise—it's worth it. Imagine that subwoofer levitating to the center of the room. It is still draped in the sheet but floating. It is still connected to the outlet on the wall and the sound system by cables. Imagine what that sheet would do. The sheet would still drape it, and as it rose, the sheet would drape the cables and cords, too. The rest of the sheet would remain on the walls, ceiling, and furniture, but it would be lifted by the levitating subwoofer. Where the sheet draped over the cords and cables, it would come really close to itself. Those cords and cables are the blood vessels,

lymphatics, and nerves. Where the sheet comes close together and there are cords and cables is where sheets of mesothelium covering the blood vessels, lymphatics, and nerves come close together. That's called mesentery. The thing is, the mesothelium of the peritoneal cavity is way more flimsy than that cloth sheet. So, wherever it can hold on to something, it will. It would hold onto every surface of the subwoofer, cords, and cables. It encases the organs and smooshes itself right up against those blood vessels, lymphatics, and nerves coming from the floor.

Wherever the mesothelium is in contact with a visceral organ (a named structure usually from endoderm, so not blood vessels, lymphatics, or nerves), the mesothelium is named the **visceral peritoneum**. Whenever the mesothelium is in contact with the abdominal wall, it is called the **parietal peritoneum**. Wherever the visceral peritoneum is over (like with the levitating couch) itself, blood vessels, lymphatics, or nerves, it is **called mesentery**.

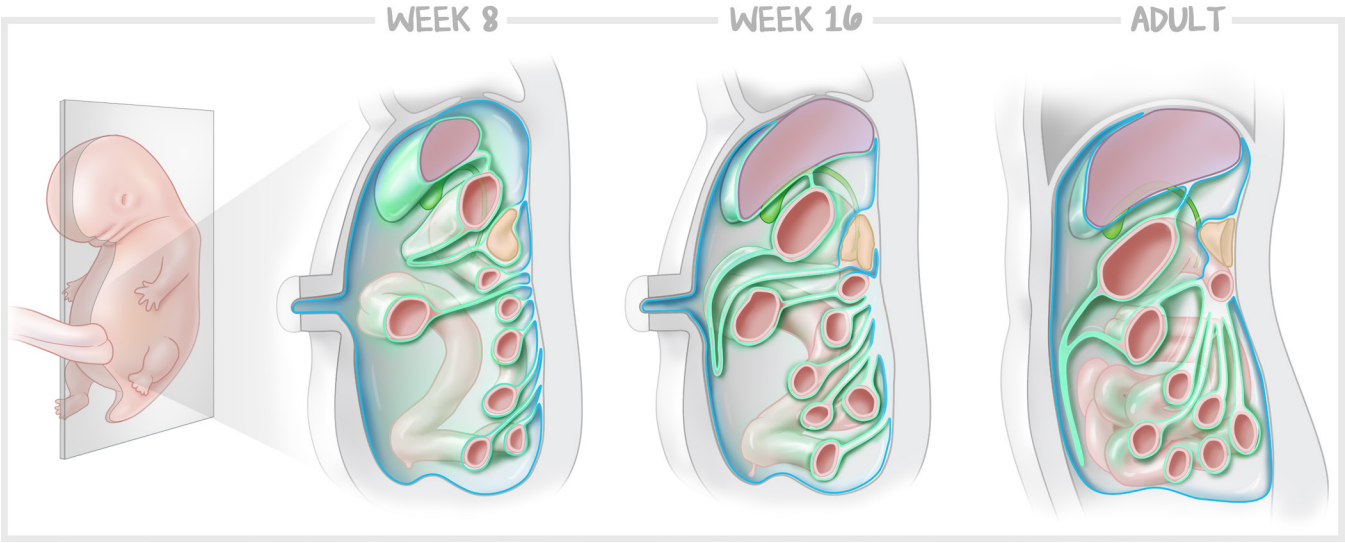

Figure 3.2: The Peritoneal Cavity Gets Pushed Around
As the gut tube develops into the organs of the abdominal cavity, these organs grow either posteriorly into the dorsal mesentery or anteriorly into the ventral mesentery. This illustration shows them growing with the ventral mesentery removed. You should pay attention to the progression of organ growth and what color the peritoneum is—green or blue. As those organs grow (a slow, gradual process), the flimsy mesothelium gives way. It doesn't break, but rather envelops the organs, forming their serosa. It also envelops their blood vessels, lymphatics, and nerves, which emanate from the back of the abdominal compartment. Wherever the mesothelium of the peritoneal cavity envelops organs (including blood vessels, lymphatics, and nerves), that mesothelium is called the visceral peritoneum (green). Wherever the mesothelium of the peritoneal cavity does not envelop any organ, it is called parietal peritoneum (green). Finally, notice the "dorsal mesentery" in the adult. The blue line of the parietal peritoneum accounts for almost all of the posterior wall, whereas the green lines of the visceral peritoneum keep returning to a common origination. In this sense, the intestines are said to be "suspended from" the posterior abdominal wall via the dorsal mesentery.

Intraperitoneal means a surgeon can grab onto it and move it without having to dissect it from the adventitia of another organ. An intraperitoneal structure is one that is lined with mesothelium everywhere except where blood vessels, lymphatics, and nerves are attached to it. At that point, it is lined with mesentery. (Again: "intraperitoneal" organs are not located *within* the peritoneal cavity. The name describes appearances to the naked eye, not histologic reality.)

Retroperitoneal describes any organ that does not bump up against the peritoneal cavity. It does have to be dissected away from the adventitia and isn't easy to move. Retroperitoneal organs are not lined with mesothelium.

Secondarily retroperitoneal means an organ has some part of it in contact with the peritoneal cavity (adventitia separated from other organs' adventitia by mesothelium) and part of it not in contact with the peritoneal cavity (adventitia mish-mashed with the adventitia of other organs).

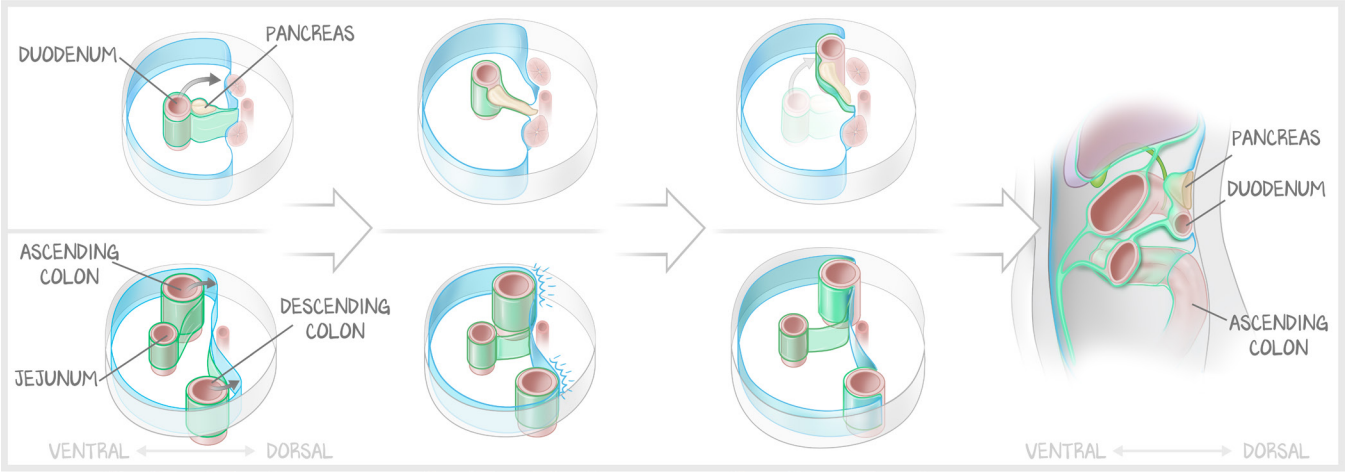

Figure 3.3: Secondarily Retroperitoneal
There are two ways for an organ to begin growing enveloped in mesothelium and then become not entirely enveloped in mesothelium. The first is simply movement, as shown by the duodenum and pancreas. They grow in such a way that they simply move backward. Whereas the other organs continue to push the mesothelium of the peritoneum around, these two retreat, encroaching on it less. The second way is illustrated by the ascending and descending colon (the same is true of the bare area of the liver). As the visceral peritoneum (green) of the ascending and descending colon come into contact with the parietal peritoneum (blue) of the posterior wall, they fuse and disappear. Later, we will demonstrate visceral peritonea coming into contact with each other (green with green), where they will fuse and persist.

No Organ is Intraperitoneal

The only thing that should be INSIDE the peritoneal cavity is fluid and a surgeon. When people say that organs are intraperitoneal, they really mean that they are surrounded on all sides by the mesothelium that lines the peritoneal cavity.

When a laparoscopic surgeon inserts a trocar and fills the belly with air, the camera is located inside the peritoneal cavity. When the surgeon points the camera up at the inside of the abdominal wall, what they see is clear, glistening stuff with some yellow stuff in it. The lining of the peritoneal cavity is only one cell thick, so it is not apparent to the naked eye or to the camera. The camera sees through this lining to the connective tissue of the abdominal wall—the transversalis fascia. Fascia and peritoneum are not the same thing. But because fascia has adipose in it, and the peritoneal cavity's lining is so thin, the surgeon can see the adipose in the fascia that encircles the peritoneum. To the naked eye, as to the laparoscopic camera, the borders of the peritoneal cavity appear to be defined by the fascia, and because the mesothelium of the peritoneal cavity is invisible, the organs appear to be floating in the fluid of the peritoneal cavity . . . hence the misconception that they are "intraperitoneal."

When the surgeon looks down at the patient with an opened abdominal cavity, what they see is a mat of fat. This is the greater omentum. Move that out of the way. Tada! Bowel. The bowel has fatty connective tissue through which vessels, nerves, and lymphatics run (adventitia). That adventitia is not lined with the mesothelium of the peritoneal cavity, but rather it is encased in sheets of simple squamous epithelium, the mesothelium, the lining of the peritoneal cavity. Because that mesothelium is lining the peritoneal cavity, it is given the name peritoneum.

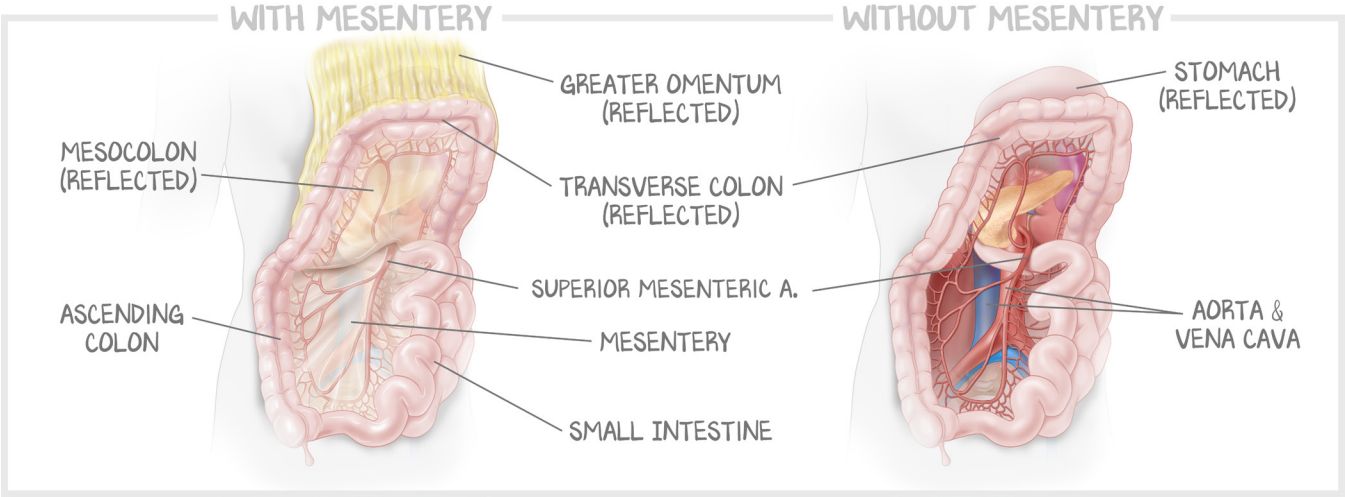

Figure 3.4: No Organ is Intraperitoneal
This illustration shows things as you would see them when the belly is opened. Because the belly is open, you have already gone through the SAT, DAT, aponeuroses, and parietal peritoneum. You are in the peritoneal cavity. In this illustration, the greater omentum and colon are reflected (lifted up and out of the way) over the stomach. On the left, the mesentery is intact. What stands between you and the pancreas, small intestine, colon, blood vessels, etc., is a peritoneal lining. You can see through the shiny flimsy lining to see the organs behind and underneath is. On the right, the mesentery has been removed. What do you see? The same thing. All organs are behind the peritoneum, outside the peritoneal cavity, connected to their blood supply, nerves, and lymphatics. Just like the levitating subwoofer, these organs are in their place, connected to the floor. Only you, the surgeon, and a small amount of lubricating fluid should ever be in the peritoneal cavity.

Mesentery, Omenta, Ligaments

Where the mesothelium lines big visceral organs, the mesothelium is called serosa. It's named that because when you cut out an organ with serosa, it appears as if the mesothelium belongs to the organ. The mesothelium is draped over the organ just as it drapes over blood vessels, lymphatics, and nerves. The serosa does NOT belong to the bowel. It is the lining of the peritoneal cavity that was taken with the resected bowel. When that sheet of mesothelial cells completely surrounds the big chunky organ, the parts of that sheet of continuous cells that were on either side of the engulfed organ come very close together and fold over each other. When the mesothelium folds over (or reflects on) itself in this way, it gives the appearance of a **dual-layered structure**. In between those two layers are often found blood vessels, lymphatics, and nerves. They are traveling from the "retroperitoneal space" to their organ. Wherever there are two sheets of mesothelium coming close together, it is called **mesentery**.

Mesentery sometimes has blood vessels, lymphatics, and nerves between those two layers. Sometimes it doesn't. When there are blood vessels, lymphatics, and nerves between those two layers, because both layers are so thin, you can see those blood vessels, lymphatics, and nerves. When there aren't any of those structures there, you can take your finger and poke a hole right through it (which is called dissecting it). That poking-through of the mesentery cannot be perceived by your eye or by your finger. What actually happened was you penetrated two layers of mesothelium with some adipose in between. There is often adipose tissue within the mesentery, which gives the mesentery weight—without the adipose, you couldn't even perceive the mesentery. The point is, surgically speaking, it's a thin see-through film that cannot be perceived as a sheet of cells lining the peritoneal cavity when you hold it up in the OR.

In the abdomen, the **mesentery** is the two layers of mesothelium that get close together through which blood vessels, lymphatics, and nerves run, where the origin of those layers is the abdominal wall. In the abdomen, a **ligament is mesentery** that connects two organs. In the abdomen, an **omentum is a ligament** that attaches organs to the stomach. Mesentery, omentum, ligament, mesocolon,

mesoappendix, mesowhatever are all the same thing. They are all the peritoneal cavity being pushed around. Back before medical science knew about mesothelium, certain structures got named for their relative gross anatomy relationship.

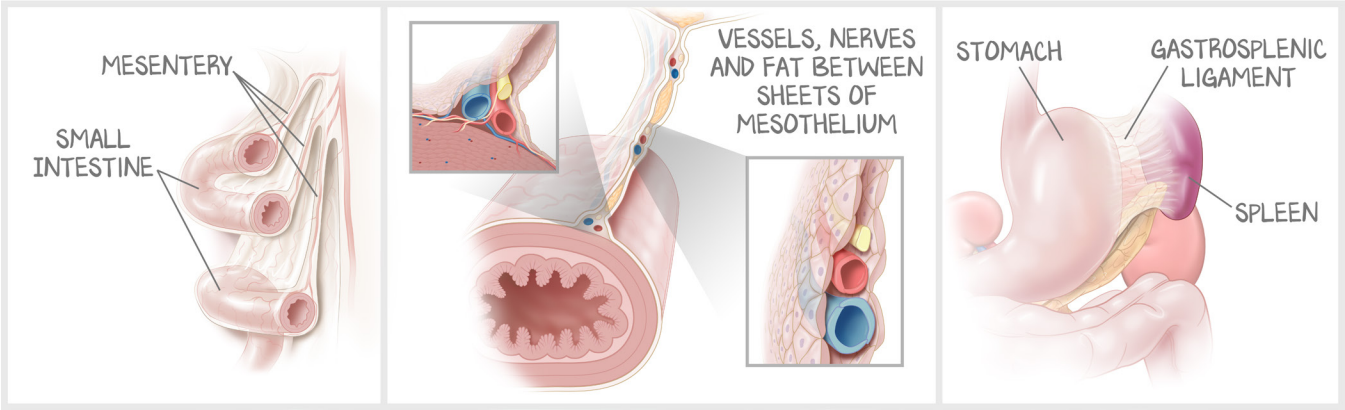

Figure 3.5: Mesentery, Omenta, and Ligaments
The peritoneum is simple squamous epithelium. It forms a sheet of cells. As the visceral organs grow up against it, that sheet gives way. When that sheet envelops an organ, it is given the name serosa. It is one continuous sheet of cells. But because an organ is pushing against that sheet of cells, there is a top sheet and a bottom sheet relative to the organ. As the organ continues to grow, it brings blood vessels, lymphatics, and nerves with it. These are not as large as the organs, so the sheet on the top of the organ (now atop the blood vessels, lymphatics, and nerves) and the sheet on the bottom of the organ (now below the blood vessels, lymphatics, and nerves) come really close together. Sometimes there is some adipose; sometimes there are blood vessels, lymphatics, and nerves. Regardless, when two sheets of mesothelium (relatively, since they are part of the one continuous sheet of mesothelium) get really close to each other with blood vessels, lymphatics, and nerves between them, medical science called that mesentery. When mesentery is between two organs, medical science named it a ligament. When mesentery is between the stomach and another organ, medical science named it omentum.

Developmental Mesenteries

During embryonic development, the one peritoneal cavity surrounds the developing gut tube. In front of the gut tube (anterior is **ventral** in the developing embryo) is a giant abdominal cavity (into which the organs will grow). It is lined with mesothelium. High up in that cavity (cranial, superior), there is a connection between the abdominal wall and gut tube. It is mesothelium folded really, really close on itself. This is the **ventral mesentery**. In the back of the gut tube (posterior is **dorsal** in the developing embryo) is a connection to the posterior abdominal wall. It is mesothelium folded really, really close on itself. This is the **dorsal mesentery**. Low down in the peritoneal cavity (caudal, inferior), there is only the dorsal mesentery. For the length of the gut tube below the diaphragm, from top to bottom, there is always a dorsal mesentery. But the ventral mesentery isn't present for the whole length of the peritoneal cavity because in front of the gut tube is the yolk sac and what will become the umbilical cord. It is that duct that the intestines will grow into and do their twist. But because the yolk sac is in between the mesoderm that could be mesentery and the gut tube, there is **only a dorsal mesentery** for the entirety of the posterior abdominal wall, and a **ventral mesentery** found only for about half of the anterior abdominal wall. There would have been TWO peritoneal cavities, but because the ventral mesentery isn't present in the inferior/caudal peritoneal cavity, the two peritoneal cavities become one.

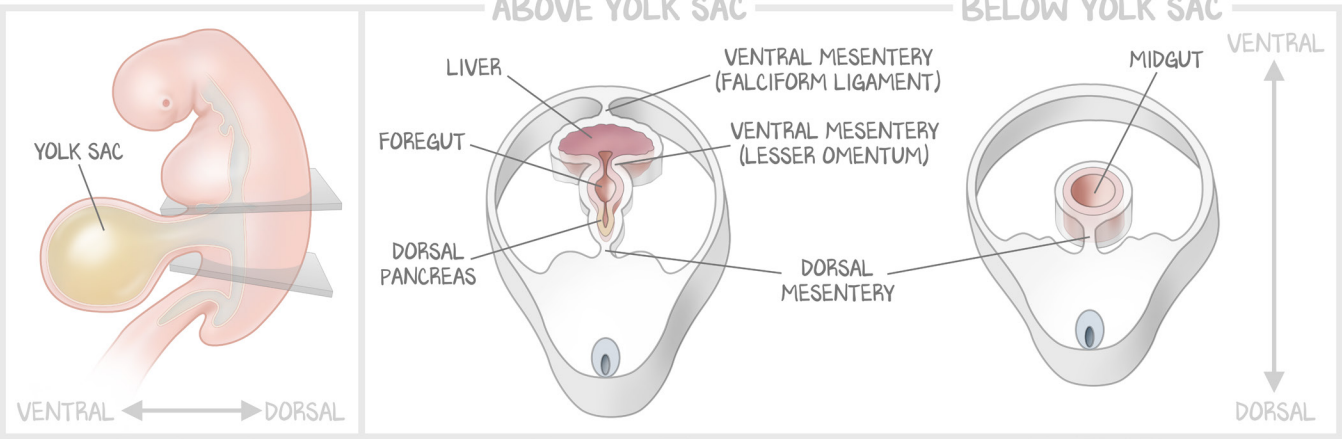

Figure 3.6: Setting the Stage—Upper Mesentery and Lower Mesentery
Although they are continuous with each other (there is one peritoneal cavity), in learning the development of the peritoneal cavity, it becomes useful to separate it into two upper cavities (divided by the ventral and dorsal mesentery) and one lower peritoneal cavity (only a dorsal mesentery because the ventral is taken away down the yolk sac). Also, notice we have placed the neural tube at the bottom, representing these slices as you would see abdominal slices of an adult CT. This is different from embryology convention but done to train you to think like a provider of adult medicine, not an embryologist.

Also, notice what is shown in Figure 3.6. The ventral mesentery isn't present because of the presence of the yolk sac. But on the outside of that yolk sac is more mesoderm that could have been ventral mesentery. And what did we learn about the mesodermal structures above the abdominal cavity? Abdominal muscles, ML, and DAT. How do the mesoderm-derived ML and DAT know to form, but only over the abdominal cavity? Probably because of its relationship with the yolk sac.

Development of the Upper Peritoneal Cavity

Where there is a ventral mesentery and a dorsal mesentery, there will grow the liver, gallbladder, pancreas, stomach, and spleen. The spleen is derived from **mesoderm** and will not be discussed again, though it is unique in that it is coated in mesothelium and derived from mesoderm, whereas the other viscera are derived from endoderm. While the gut tube organs grow and compress the peritoneal cavity, the **transverse shelf** (future diaphragm) grows from the mesoderm in front (ventral) in the direction that is towards the back (dorsal). This will become the future diaphragm, and it will grow around the existing structures—aorta, vena cava, esophagus—to become the final diaphragm that separates the thorax from the abdomen.

The liver will grow the most anteriorly (ventral) and will grow the largest. The liver starts encased in mesothelium. It grows up against the peritoneal cavity, draping it and its connection to the gut tube in mesothelium. As it grows, it expands into the peritoneal cavity. The transverse shelf is growing over the top of the peritoneal cavity, so the transverse shelf (the future diaphragm) has a sheet of mesothelium running along it. As the liver grows up against the transverse shelf (diaphragm), the mesothelial lining of the bottom of the diaphragm and the mesothelial lining of the top of the liver fuse and disappear, generating the bare segment of the liver where the adventitia of the diaphragm becomes continuous with the adventitia of the liver. The ventral mesentery anterior (ventral) to the liver will become the **falciform ligament** and will connect the liver to the anterior abdominal wall.

The pancreas starts encased in mesothelium. It grows into the ventral mesentery, but also the tail grows back towards the aorta. Thus, the pancreas is secondarily retroperitoneal (only partially lined with mesothelium).

The stomach is a dilation of the gut tube past the esophagus. It begins cranial (superior) to the trajectory of the transverse shelf. The stomach is attached to both ventral mesenteries connecting it to the liver (the lesser omentum) and dorsal mesentery connecting it to the posterior abdominal wall. It then does a little turn to find itself on the left side of the abdomen. It tugs harder on and twists the ventral mesentery (allowing for the opening to the lesser sac/bursa) while also giving the dorsal mesentery some slack. This forms the lesser bursa, the lesser sac. The stomach's relation to the greater omentum will be told from the context of the colon.

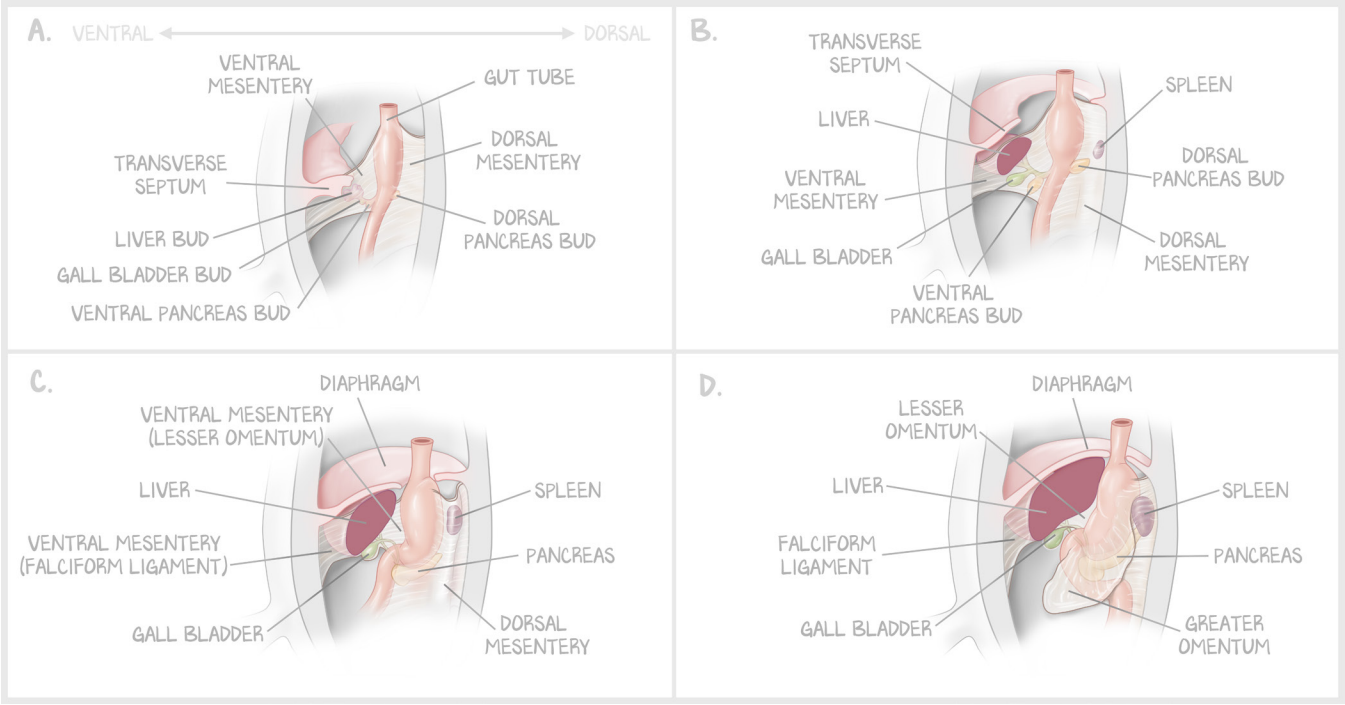

Figure 3.7: Development of the Upper Peritoneal Cavity
(a) The stomach is the gut tube, suspended by both ventral and dorsal mesentery. The liver and pancreas are shown to be developing within the ventral mesentery. (b) The transverse septum (future diaphragm) migrates to separate the thorax from the abdominal compartment. The heart (not depicted) is located just above the transverse septum, and the liver just below it. The spleen (derived from mesoderm, not endoderm) develops in the dorsal mesentery. (c) the stomach does a little twist to the right, tensing the ventral mesentery attached to the liver (forming the lesser omentum and moving the duodenum and pancreas into their secondarily retroperitoneal position. (d) The stomach twist relaxes the dorsal mesentery, which hangs off the front of the colon and will eventually fuse to form the greater omentum. The liver fuses with the diaphragm at the bare spot of the liver, and an exaggerated falciform ligament demonstrates the remnant connection of the ventral mesentery to the liver. Not visible is the lesser sac, behind the stomach, accessed by going under the lesser omentum (the duodenal-hepatic ligament of the lesser omentum, but that level of detail is not shown).

Development of the Lower Peritoneal Cavity

The lower half is all about dangling in ventral mesentery and fusion of mesothelium. Here's the thing—the small intestine and large intestine are tubes. They are tubes that grow up against the peritoneal cavity, pushing their way in to be coated in mesothelium. The dorsal mesentery (the one in back) is the common connection to the posterior abdominal wall. Blood vessels, lymphatics, and nerves make their way to their respective segment of the intestine. There are no ligaments. It just gets awfully convoluted because of how long the segments are. But it is important to remember that no matter how long the segments of mesentery are, the entirety of the small intestine and large intestine are not far from their arterial supply.

The jejunum and ileum grow. They grow into the umbilical cord's space, into the space left behind by the yolk sac. So too does the colon. If no rotation occurred, the entire colon would end up on the left of the abdomen and the entire small intestine on the right. The rotation happens as described in the colon lesson—fists over fists, limited turning of elbows.

A couple of important **fusions of mesothelium** happen. If they didn't, it would be super simple—the GI tract growing up against and pushing its way into one peritoneal cavity, which coats the tract in sheets of mesothelium, producing mesentery. While the liver grows in the right upper quadrant, the stomach gets moved over to the left. This tenses the lesser omentum (aka remaining ventral mesentery between liver and stomach) but relaxes the greater omentum (the stomach's dorsal mesentery). It continues to grow in this relaxed state downward (caudally) and covers the transverse colon. The mesothelium of the dorsal mesentery of the stomach is continuous with the mesothelium of the dorsal mesentery the transverse colon is coated in.

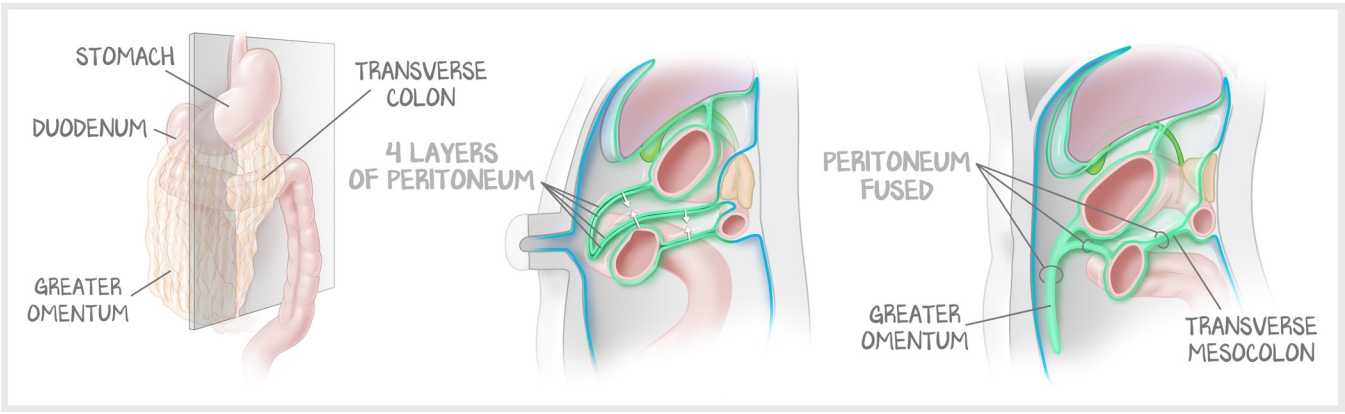

Figure 3.8: Sometimes It Fuses
When visceral peritoneum meets parietal peritoneum (green and blue, respectively), they fuse and disappear, just like in the bare area of the liver and diaphragm. When visceral peritoneum meets visceral peritoneum (green and green, as shown in this illustration), they fuse and persist. The peritoneal cavity is one continuous cavity. It is divided into a greater sac and a lesser sac. The lesser sac is created by the fusion of the stomach's visceral peritoneum and the transverse colon's visceral peritoneum (greater omentum) and the fusion of the mesentery to form the transverse mesocolon (the transverse colon's mesentery).

The ascending and descending colon are **secondarily retroperitoneal**. They start their development draped in mesothelium. As they approach the posterior of the peritoneal cavity, the visceral and parietal peritoneum fuse. The ascending and descending colon retain contact with the peritoneal cavity, are coated in mesothelium, and are connected to their vascular supply through mesentery on the lateral edges and the anterior (ventral) edge. But their adventitia becomes continuous with the "retroperitoneal" adventitia of "retroperitoneal" organs.

Above the level of the anal canal—that which is irrigated by middle and superior rectal arteries and veins—the mesothelium ceases to coat the gut tube. The mesothelium covers the uterus and bladder, and then reflects upward on the abdominal wall. All blood vessels, lymphatics, and nerves that are in the abdominal cavity but aren't in the peritoneal cavity run under the mesothelium, under the lining of the peritoneal cavity between the peritoneum and the rectus sheath. They are pressed between the peritoneal cavity's lining and the beginning of the abdominal wall. "Intraperitoneal" organs receive their blood supply through mesentery. "Retroperitoneal" organs (such as the uterus, Fallopian tubes, and bladder) receive their blood supply from local arteries just under the peritoneal lining.

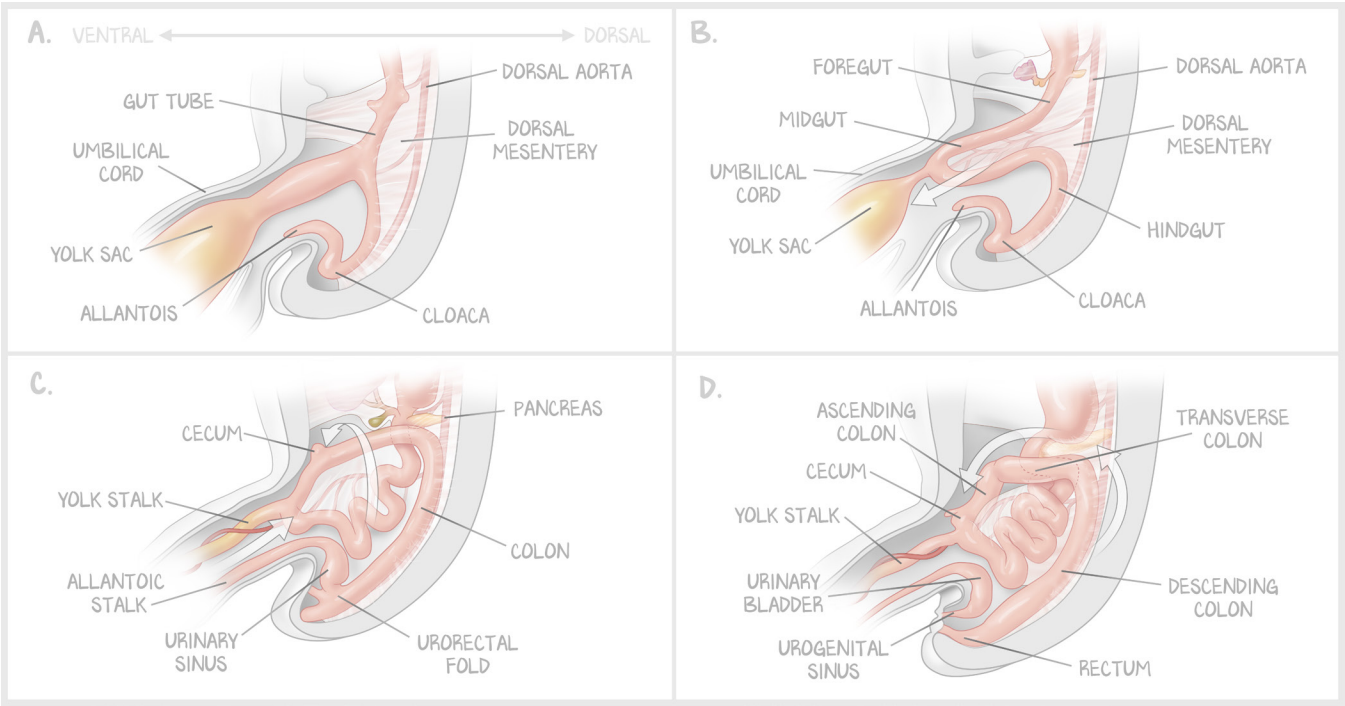

Figure 3.9: Development of the Lower Peritoneal Cavity
(a) There is no ventral mesentery because what would have been the mesoderm that made the ventral mesentery is down at the end of the yolk sack, forming the umbilical cord. Instead, the gut tube maintains a connection to the yolk stalk, through which it will exit and twist. (b) The foregut, midgut, and hindgut already have their aortic connections, and the organs develop in the dorsal mesentery. Thus, unlike the upper peritoneal cavity, where the organs are connected to the front and back walls, the lower peritoneal cavity has its organs suspended by dorsal mesentery only. (c) and (d) depict the 270-degree twist that brings the colon into its proper position and the development of a distinct rectum from the urogenital sinus.